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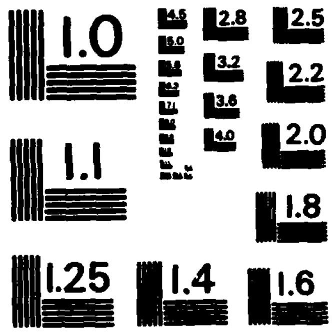

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ANNUAL SUMMARY REPORT

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20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

Nonlinear properties of solids and liquids are studied. Both pulsed and cw ultrasonic waves are used in the ultrasonic measurements which are made by electronic as well as optical techniques. Nonlinear properties of solids of cubic, hexagonal, and trigonal symmetries are described in terms of third-order elastic constants which can be measured between room temperature and 4°K; those of liquids are described in terms of the ratio B/A of coefficients in the equation of state. Nonlinear diffraction theory is considered. Keywords;

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I. ANNUAL SUMMARY REPORT

A. Apparatus Modification and Refinement During the Past Year

Important developments have taken place in apparatus construction and refinement which open up the possibility to do meaningful experiments. The developments are both in apparatus refinement and in improvement in skill level of the personnel.

1. The goniometer-within-a-goniometer is completed and is in place in the schlieren system. This apparatus allows precision alignment of sample surface with light beam and ultrasonic beam, and possibly will be useful to other experimenters.

2. Apparatus for studying the diffraction of light has been assembled with the intention of going into detail on some problems in Bragg diffraction.

3. Thanks to the efforts of a visiting solid state physicist, David Gerlich, the apparatus for studying nonlinear distortion of ultrasonic waves in solids has been reworked. The new 60 MHz IF amplifier had poor rejection ratio for the 30 MHz signal. High pass filters have improved the situation to the point that measurements again can be made. Efforts are continuing in the direction of providing an electronic gate to improve signal-to-noise ratio, however.

B. Nonlinear Distortion of Ultrasonic Waves in Crystals of Hexagonal and Trigonal Symmetry (Pure Mode Directions)

Since the beginning effort at deriving the nonlinear wave equation for hexagonal and trigonal symmetry by Jacob Philip, we have made a more thorough investigation than we originally thought would be necessary. Technical Report No. 22 by Philip and Breazeale covers the pure mode directions along the hexagonal symmetry axis and the basal plane, but ignores the pure mode

directions tangential to a cone whose apex angle is bisected by the symmetry axis and whose apex angle is a function of the second-order elastic constants of the hexagonal crystal in question. Technical Report No. 22, then, is correct but incomplete. It does present an accurate description of the mathematical procedures for deriving the nonlinear wave equation in crystals of any symmetry for directions known to be pure mode directions, however, and applies it to hexagonal symmetry.

Technical Report No. 23 takes up the subject in even more detail and not only describes a general procedure for finding the pure mode directions but also applies the procedure to hexagonal and trigonal symmetries. Then rotation matrices are used to derive the nonlinear wave equation for longitudinal waves propagating in the pure mode directions—all of them! The two technical reports present an essentially complete mathematical development of the subject for those crystals which do not exhibit piezoelectricity.

C. <u>An Approach to a Nonlinear Diffraction Theory</u>

After the approach to a nonlinear diffraction theory of solids described last year, it became apparent that the approach of Tjøtta and Tjøtta based on the parabolic approximation would be useful to the understanding of the diffraction field of a Gaussian transducer. The mathematical simplification resulting from the use of the Gaussian input function has made it possible to give an analytical solution in both the linear approximation and the nonlinear approximation to describe the diffraction field of a plane transducer and a focussed beam as well. Such results are of importance in underwater acoustics applications where plane transducers most often are used and in acoustical microscopy which uses nonlinear effects in a focussed system to improve resolution.

The existence of a Gaussian transducer has made possible an experimental confirmation of the nonlinear diffraction theory of Tjøtta and Tjøtta. In addition, a more analytical form of the function that describes the shape of the fundamental and second harmonic diffraction field has been derived. This solution has been compared with measured values of the fundamental and second harmonic distribution and seems to agree within experimental uncertainty.

The theory of a focussed Gaussian beam has been developed and is to be presented at the Nashville Meeting of the Acoustical Society of America. Some experimental testing of a focussed Gaussian beam has taken place, but with even the smallest probe one encounters resolution problems near the focus. Nevertheless, the fact that the second harmonic focus is more narrow than the funcamental focus is demonstrable.

D. Effect of Error Propagation on the Magnitude of K_2

A statistical analysis of error propagation in the evaluation of the second-order elastic constant combination K_2 required in determining the third-order elastic constants K_3 has been made. The results define the means by which the most accurate values of K_3 can be determined. The results are to be presented in the Master's thesis of Madhu Puri which will be issued as a technical report.

E. New Directions of Research

1. Ultrasonic Wave Propagation in Nonpure Mode Directions

We are accumulating experience with propagation of finite amplitude ultrasonic waves in directions other than pure mode directions, as it is conceivable that the coupling parameters among some of the modes might be determinable from experimental data. Derivation of the corresponding

mathematical representation of the coupling parameter in terms of second-order and third-order elastic constants then would enable one to evaluate another linear combination of third-order elastic constants. Such a result would be a major contribution to the nonlinear acoustics of solids and would constitute a new field of endeavor.

2. The possibilities opened up by the work of David Gerlich with the apparatus for measuring nonlinear distortion of ultrasonic waves in solids are very numerous. Not only measurement of third-order elastic constants, but also correlation of such measurements with other physical properties, offer a fruitful field of endeavor.

3. Our experience with helping Mr. Cao to take data on $KMgF_3$ had underscored an important attribute of our technique: it is able to provide TOEC data on samples that are too fragile to measure by any other technique. Before coming to our laboratory Mr. Cao had tried in vain to take data on sound velocity as a function of unaxial stress. The $KMgF_3$ sample was just too fragile.

4. A very simple technique for studying the diffraction field has been introduced recently: propagation of an ultrasonic beam through a dye dissolved in water causes the dye to impregnate a paper suspended in the beam. This turns out to be a simple and effective means for visualizing the amplitude distribution in the field. It is being used, in particular, to map the field of a Gaussian transducer.

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